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Peritoneal dialysis catheter implantation in Germany – retrospective, nationwide analysis of all cases (2011–2021)

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Abstract

Background: Strengthening peritoneal dialysis (PD) utilization in Germany is crucial to ensure dialysis care for patients with kidney failure in an aging population with a predicted decline in the number of health care professionals. PD catheter implantations are a key indicator for the utilization of PD. We performed the first comprehensive study on PD catheter implantation rates and inpatient outcomes in Germany.

Methods: For this retrospective study we queried the diagnosis related group statistics of the Federal Statistical Office of Germany for the years 2011 to 2021, which includes demographics and information on the medical course from all German inpatient cases.

Results: During the observation period, 14,158 PD catheters were implanted, with an average of 1272 ± 127 (mean ± standard deviation) per year. Nationally, annual implantation rates were stable, without notable changes over time. Notably, there were significant regional differences in implantation rates within Germany. The average patient age at the time of PD catheter implantation was 59.7 years, with a male-to-female ratio of 1.7:1. During the hospital stay for PD catheter implantation, 517 patients (3.7%) died. Centers with higher implantation rates had more favorable outcomes. Age, number of comorbidities and certain comorbidities (e.g., cancer and heart failure) were associated with higher mortality. The length of stay in the hospital for PD catheter implantation was 19.5 (±22.3) days.

Conclusion: Our analysis reveals that relatively few PD catheters are implanted in Germany each year. Over the observation period, there was no substantial increase, indicating a continued underutilization of PD in Germany.

Keywords

Peritoneal dialysis, catheter implantation, healthcare provision, Germany

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Introduction

With approximately 850 million patients affected worldwide, chronic kidney disease (CKD) represents a significant burden on global health.[1] As populations age and the prevalence of comorbid conditions such as diabetes and hypertension rises, the incidence of CKD can be expected to increase substantially in the coming years.[2,3] The management of kidney failure (KF), the final stage of CKD, presents considerable challenges due to the complexity of care and the substantial financial implications on healthcare systems.[4,5] It is estimated that the health care cost of treating dialysis patients in Germany amounts to more than 3 billion Euros annually.[6] Effective and efficient therapeutic strategies are critical to mitigate this impact and to improve patient outcome.

Like many other nations, Germany faces a two-pronged demographic challenge in the context of health care provision. Firstly, the aging population is leading to an increase in the number of individuals with CKD and other chronic illnesses, thereby escalating the demand for medical services and long-term care.[7,8] Secondly, there is a simultaneous decline in the number of healthcare professionals, exacerbating the strain on an already overburdened healthcare system.[9] This dual challenge underscores the urgent need for innovative and sustainable approaches to manage CKD and KF effectively.

Possibly the greatest opportunity to address these issues in Germany lies in the increased utilization of peritoneal dialysis (PD). Compared with in-center hemodialysis (HD), PD can inherently provide numerous benefits for patients, including quality-of-life advantages reported in some studies, technical simplicity and a lower CO_2 footprint as regular commute to the dialysis facilities is unnecessary.[10,11] Addressing the challenges of the above-mentioned resource problems, PD offers significant advantages in terms of cost-effectiveness and resource allocation.[12–14] Despite its potential benefits, PD rates in Germany have historically been low compared to HD.[15] With close to 6% of all dialysis patients, prevalent PD patients Germany trails towards the lower end globally in terms of PD utilization.[15,16] Leveraging PD more extensively could therefore be a crucial strategy in meeting the growing demand for KF treatments while managing healthcare resources more efficiently. However, the lack of a national dialysis registry makes it very difficult to implement targeted strategies for improvement.[17] To address this challenge, we conducted a study using PD catheter implantations as a surrogate measure of PD utilization, given their role as a reliable and objective proxy for the initiation of PD. Specifically, our study examines the following three key questions:

1. Utilization – How frequently were PD catheters implanted in Germany over a decade, and what trends were observed over time?
2. Patient characteristics – What were the demographic and clinical profiles of patients selected for PD catheter implantation?
3. Outcomes – What were the immediate outcomes associated with PD catheter implantation?

Methods

Study design and data source

We conducted a retrospective analysis of all in-hospital PD catheter implantations in Germany from 2011 to 2021. The data source for this nationwide analysis was the German Federal Statistical Office (GFSO; Statistisches Bundesamt). The dataset comprehensively covers all inpatient cases in Germany, obligatorily including patient demographics and hospital characteristics. Germany's health care reimbursement system mandates that PD catheter implantations occur in the inpatient setting, ensuring that all procedures are captured in the GFSO dataset and allowing for comprehensive analysis.

Data on the medical course are available by querying information on diagnoses according to the International Classification of Diseases (ICD) 10th Revision, German Modification, and German operation and procedure classification (Operationen- und Prozedurenschlüssel; OPS) codes per individual database entry. The specific datasets are cited in the supplementary material. We identified PD-catheter implantations by a combination of OPS-key 5–549.2 (implantation of a tunneled catheter into the abdominal cavity) and ICD-Code N18.5 (stage 5 CKD). To assess the accuracy of this selection, we conducted additional queries capturing any form of PD following catheter implantation.

Information on the German population was based on data from the GENESIS Database of the GFSO, basis for inhabitant numbers was the census of 2011.[18]

Ethics

This data analysis was granted by the GFSO, which ensures anonymity and thus adherence to data privacy regulations.[19]

Syntax creation and statistical analysis

For the query of the database, we used syntax files created in R (version 4.4.1). Results were reported as mean ± standard deviation (SD) for normally distributed data and median with interquartile ranges (IQR) for non-normally distributed data. Trends in annual total PD catheter implantations were analyzed using simple linear regression, with the slope (β_1) representing the annual change. The coefficient of determination (R^2) was provided to assess the model's goodness of fit.

To assess clinical outcomes, we employed generalized linear mixed models (GLMM) and linear mixed models (LMM). For binary outcomes (death, intensive care unit (ICU) admission, and HD), we used GLMMs with a binomial distribution and a logit link function, including a random intercept for hospitals to account for between-

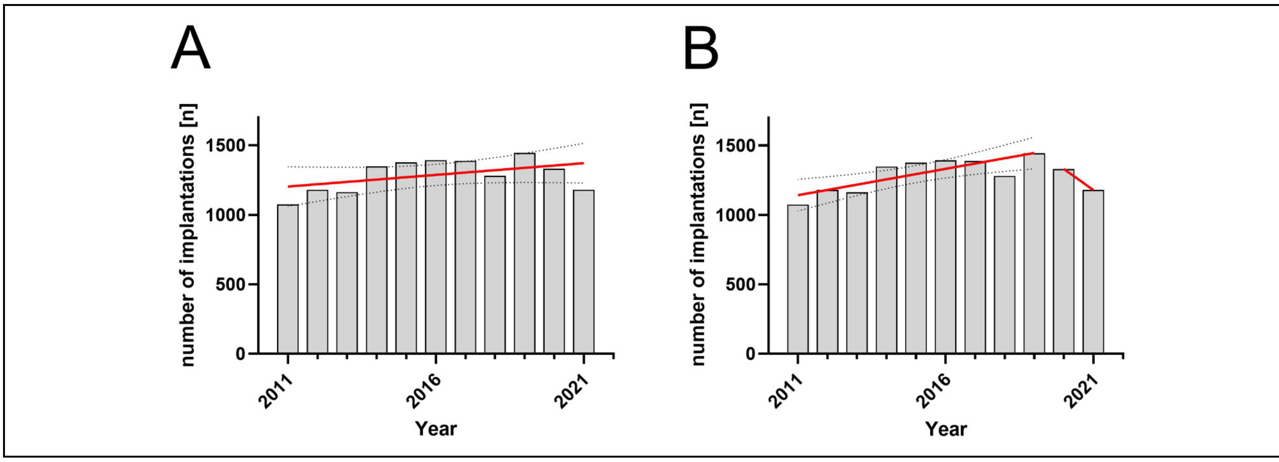

Figure 1. (A) Total PD catheter implantations in Germany 2011-2021 with overall trend analysis and (B) trend analyses before and after the begin of the Covid-19 pandemic. Linear regression analysis did not reveal a significant change in total annual PD catheter implantations from 2011 to 2021 (β_1 = 16.84; R^2 =0.22; p = 0.15). Excluding the years 2020 and 2021, the analysis shows a significant, albeit small increase in total annual PD catheter implantations before the begin of the Covid-19 pandemic (β_1 = 38.02; R^2 =0.67; p = 0.007), followed by a decline during 2020 and 2021 (β_1 = -152.0; R^2 omitted due to the availability of only two data points, which inherently results in R^2 = 1.0).

hospital variability. Fixed effects included patient characteristics (age, sex, Elixhauser comorbidity score,[20] selected comorbid conditions) and hospital type by surrounding population density. For length of stay (LOS) as a continuous outcome, we applied an LMM fit by restricted maximum likelihood (REML), with hospitals as a random intercept. The same patient- and hospital characteristics were included as fixed effects.

Model performance was assessed using the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) for GLMMs, while the REML criterion was used for LMM. Variability at the hospital level was quantified using the intraclass correlation coefficient (ICC).

Differences in outcomes between hospitals depending on the number of annual PD catheter implantations were assessed with the Chi-square test for binary outcomes and analysis of variance (ANOVA) for LOS.

Figures

Figures were created in R (version 4.4.1), GraphPad Prism 10 (Graphpad Software, Inc. 2023) and composed in CorelDraw X8 (Corel Corporation). Specific packages are listed in the supplementary materials.

Results

Utilization patterns of PD catheter implantation in Germany

From 2011 to 2021, 17,654 tunneled abdominal catheters were implanted in Germany. Of these, 14,158 were considered as PD catheters based on the occurrence of a diagnosis of stage 5 CKD and at least one PD treatment, as detailed in Supplementary Table S1 and Figure S1. On average there were 1272 ± 127 (mean ± SD) implantations per year with a minimum of 1075 in 2011 and a maximum of 1444 in 2019, as shown in Figure 1A.

The linear regression analysis did not reveal a significant change in total annual PD catheter implantations from 2011 to 2021 ($\beta_1 = 16.84$; $R^2 = 0.22$; $p = 0.15$). We repeated the trend analysis, excluding the years 2020 and 2021 to mitigate the influence of the Covid-19 pandemic (Figure 1B). This analysis showed a significant, albeit small increase in total annual PD catheter implantations ($\beta_1 = 38.02$; $R^2 = 0.67$; $p = 0.007$), followed by a decline during 2020 and 2021 ($\beta_1 = -152.0$; R^2 omitted due to the availability of only two data points, which inherently results in $R^2 = 1.0$).

We further analyzed PD catheter implantations across German federal states and found substantial regional differences (Figure 2A). States in western Germany had generally higher PD catheter implantation rates. The regional differences were mostly stable over time; however, certain states, such as Saarland, exhibited abrupt notable changes (Figure 2B). Detailed Information on each federal state is provided in the Supplementary data (Table S3).

Patient demographics and clinical profile

A total of 8926 men and 5231 women underwent PD catheter implantation from 2011 to 2021, approximating a 1.7:1 ratio of male to female patients. The mean age was 59.7 ± 20 years. Demographics and characteristics of the cohort are presented in Table 1. We reviewed the available diagnoses for putative causes of KF and identified conditions related to metabolic syndrome, such as hypertension or diabetes, in 50% of cases. In 25% of patients, we found a

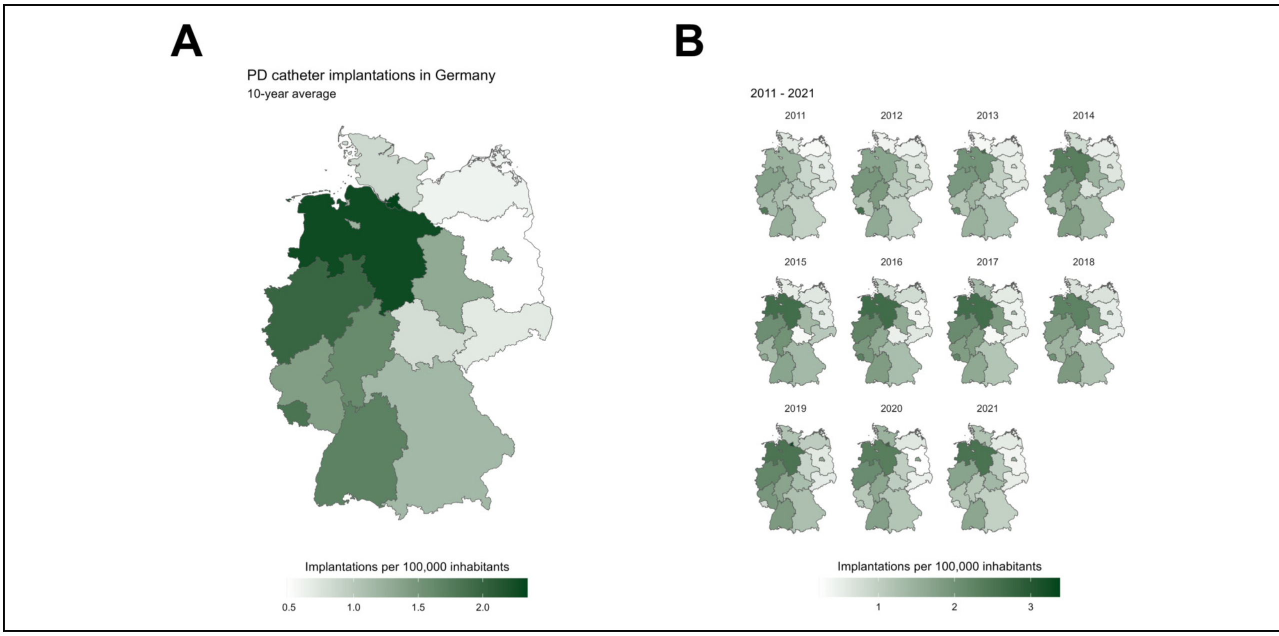

Figure 2. Regional distribution of PD catheter implantation rates: (A) Average PD catheter implantation rates per 100,000 inhabitants in Germany from 2011 to 2021. (B) PD catheter implantation rates per 100,000 inhabitants from 2011 to 2021 by year.

systemic disease, including cardiorenal, hepatorenal, or inflammatory systemic disorders. Additionally, 12% of cases were attributed to kidney diseases, such as autosomal dominant polycystic kidney disease (ADPKD) or glomerulonephritis (GN). These findings are visualized in Figure 3, which provides a detailed breakdown of the distribution of causes. The supplementary material contains a decision tree, by which putative causes of KF were identified and their ICD-10 codes (Table S2, Figure S2).

The analysis of comorbidities among patients undergoing PD catheter implantation revealed high prevalences of various chronic conditions. For an extensive list of comorbidities including less prevalent diseases see Supplementary data, Table S4.

Table 1. Demographics and clinical characteristics.

Variable	Value
Age, mean (±SD)	59.7 (±20)
Male sex [%]	63.05
Elixhauser comorbidity score, mean (±SD)	4.67 (±2.15)
Diabetes [%]	
Uncomplicated	21.61
Complicated	12.09
Arterial Hypertension [%]	
Uncomplicated	45.73
Complicated	32.26
Congestive Heart Failure [%]	34.66
Coronary Heart Disease [%]	25.43
Peripheral Arterial Disease [%]	12.00
Chronic Obstructive Pulmonary Disease [%]	8.46
Cancer [%]	1.24
Liver Disease [%]	6.33

Outcomes and in-hospital stay in patients undergoing PD catheter implantation

During the hospital stay in which the PD catheter implantation occurred, a total of 517 (3.7%) patients died. In 9.6% of cases, patients were admitted to the ICU during their hospital stay. Blood loss resulting in anemia occurred in 56 (0.4%) patients. However, from our dataset it was not possible to differentiate whether this was before or after PD catheter implantation and related to the procedure. Additionally, 29.8% of patients received HD during their hospitalization, of whom 12.2% required placement of a central venous catheter. From 2011 to 2021, we observed a decline in mortality, ICU admittance and additional HD as demonstrated in Supplementary data, Figure S3.

The impact of patient and hospital characteristics on in-hospital mortality, ICU admission, and HD were analyzed using GLMMs. Age, Elixhauser comorbidity score, and high-risk comorbid conditions (e.g., congestive heart failure (CHF), diabetes) were significantly associated with each of the three outcomes. However, due to convergence issues, these models did not reach a stable solution. As a result, we present our findings in the supplementary data for reference (Supplementary data, Figure S4).

The mean LOS was 19.5 (±22.3) days and showed a two-peaked pattern, with maxima at three and eight days, shown in Supplementary data, Figure S5. In general, the LOS declined from a median of 16 days (IQR 9, 29) in 2011 to

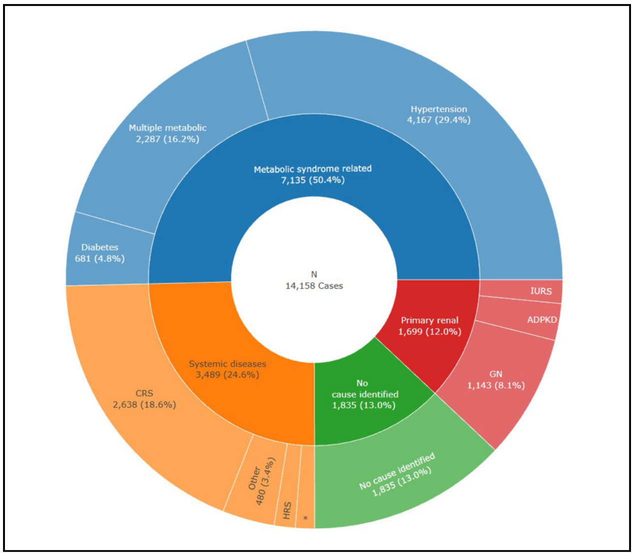

Figure 3. Sunburst plot illustrating the putative causes of KF. ADPKD: 339 (2.4%); HRS: 194 (1.4%); IURS: 217 (1.5%); Multiple systemic (*): 177 (1.3%). Abbreviations: CRS (cardiorenal syndrome), HRS (hepatorenal syndrome), GN (glomerulonephritis), ADPKD (autosomal dominant polycystic kidney disease), and IURS (interstitial or urological renal syndrome).

10 days (IQR 6, 20) in 2021, where less than 25% of the patients were discharged after 20 days. In the LMM for hospital LOS, a higher number of comorbidities was associated with a longer stay ($\beta = 4.23$ days, standard error (SE) $=$ 0.086, $p < 0.001$), while each additional year of age was associated with a shorter LOS ($\beta = -0.13$ days, SE $= 0.010$, $p < 0.001$). Population density had no statistically significant effect, and the ICC was 0.19, suggesting that 19% of the variance in LOS was attributable to hospital differences.

To compare the effect of implantation volume on outcomes, we grouped hospitals into quartiles based on annual PD catheter implantations. Hospitals in lower three quartiles performed similarly few PD catheter implantations, averaging 1.1, 2.8 and 6.7 procedures per year, respectively. In contrast, hospitals in Q4 stood out with an average of 21.6 implantations per year, indicating that a small subset of hospitals was responsible for the majority of PD catheter implantations. Table 2 demonstrates that hospitals with more annual PD catheter implantations showed significantly more favorable outcomes, with lower mortality, fewer ICU admissions, reduced need for HD, and shorter LOS.

Discussion

Low utilization and stagnancy of PD catheter implantations

Our first major finding was the overall low utilization and stagnancy of PD catheter implantations in Germany. With approximately 1300 PD catheter implantations per year, PD is a minor fraction of the approximately 37,000 newly dialyzed patients annually.[21] Although due to the lack of a national dialysis registry the number of newly dialyzed patients can only be extrapolated. This extrapolation, however, highlights an interesting point: the prevalence of PD patients is considerably higher than the fraction of PD among newly dialyzed patients. This disparity is most likely driven by the strong preference for HD in acute care settings, which aligns with a recent report on the persistently low use of PD in Europe. Despite its benefits for patients and healthcare systems, the study cites clinician bias and financial incentives for HD as key factors for PD underutilization.[22] Clinician-related barriers to PD are well documented,[23] and the decline in PD catheter implantations in 2020 and 2021 can serve as a spotlight on the strong tendency of German nephrologists away from PD. Due to higher infection risk among in-center dialysis patients, steering new dialysis patients towards PD would have been a sensible approach.[24,25] Instead, we observed a decline in PD catheter implantations. Notably, data already suggests a cost advantage for PD compared to HD, underscoring that non-financial barriers are the primary obstacles to PD utilization in Germany.[26,27]

Patient demographic and clinical profile are not the primary barriers to PD adoption in Germany

Very few medical contraindications for PD exist, and yet certain conditions such as old age or specific comorbidities may be seen as relative contraindications.[28–30] Although, in clinical practice, eligibility is additionally shaped by social factors and the patient's capacity for self-care. Our analysis revealed age and sex distributions consistent with those reported in the German dialysis population.[15,21] The

Table 2. Hospitals grouped into quartiles by the amount of PD catheter implantations performed annually.

Quartile	Total PD catheters implanted [N]	Age [years ± SD]	Mortality [%]	ICU admissions [%]	HD during stay [%]	LOS [mean ± SD]
1st	507	60.80 ± 18.51	6.51	18.94	40.04	25.94 ± 31.66
2nd	1256	60.14 ± 20.29	3.90	11.31	36.23	22.22 ± 24.74
3rd	2961	57.03 ± 22.50	4.02	9.83	33.23	22.88 ± 25.97
4th	9434	60.42 ± 19.06	3.35	8.80	27.35	17.76 ± 19.76
			$p = 0.0015$	$p < 0.0001$	$p < 0.0001$	$p < 0.0001$

primary causes of KF in our cohort align with trends observed in the broader dialysis population, where diabetes and hypertension remain the leading contributors.[31] Given the similarities across dialysis populations, their demographics and clinical profiles are almost certainly not the primary barrier to PD utilization. This interpretation is reinforced by the substantial regional differences we observed: despite comparable patient characteristics, PD utilization varied markedly across federal states. It highlights that barriers to PD uptake extend beyond patient characteristics and include factors such as patient preferences, limited home-care support, and awareness, while the abrupt year-to-year shifts in smaller states show that PD availability in Germany often depends on individual clinicians rather than stable, system-wide structures. Further inquiry into these aspects, as examined in emerging research, may offer the insights required to overcome PD underutilization in Germany,[32] as the regional differences we found demonstrate that higher PD utilization is not only possible but already a reality in certain areas.

Patient outcomes improve with the number of PD catheter implantations

Our second major finding was that patient outcomes improve with the number of PD catheter implantations, with high-volume hospitals achieving significantly better results. This pattern is well-established in other surgical and interventional procedures.[33,34] Importantly, the procedural risk of PD catheter implantation itself is known to be minimal, indicating that the mortality observed in our cohort is unlikely to be procedure-related.[35]

A mortality of 3.7% is much lower compared to all incident dialysis patients, where mortality is approximately three times higher.[21] This disparity shows that, although we examined patients in an in-hospital setting, a large proportion most likely received their PD catheter with the intention of long-term therapy rather than starting dialysis in an emergency context. Accordingly, the annual number of PD catheter implantations in our cohort (approximately 1300 per year) aligns well with approximately 20,000 out of 37,000 newly dialyzed patients who continue with chronic dialysis in Germany each year, corresponding to an estimated PD share of around 6%.[15,21,36] A tendency to perform PD in palliative care settings could explain part of the high rates of death, ICU admission and additional HD.[37,38] This assumption is supported by our finding that old age, a multitude of comorbidities, and conditions like cancer and CHF were associated with higher mortality. Though, our data set does not provide information on the specific cause of death for each patient.

The overall mean LOS in our cohort was comparatively high at approximately 19 days.[39] While clinical factors, including the substantial comorbidity burden of many patients, may contribute to prolonged hospitalizations, system-level mechanisms also play an important role. In Germany, PD catheter implantation and PD training are typically combined in one hospitalization, supported by a DRG system that permits extended inpatient stays for training and the lack of reimbursement structures for outpatient PD catheter implantations or assisted PD.[40] These system-level characteristics should be considered when comparing hospitalization durations across countries.

In summary, our findings suggest that hospitals with very low PD catheter implantation volumes should consider referring patients to specialized centers that offer the necessary expertise and infrastructure for high-quality PD care. This approach aligns with the goals of the ongoing German hospital reform ("Krankenhausreform"). The reform aims to improve the quality of care by concentrating procedures in high-volume hospitals, ensuring that institutions meet strict quality standards for specific types of care.[41] Equipping hospitals with PD expertise – such as in the already existing certified HD access centers – and making them accessible to patients nationwide is the key to sustaining high-quality dialysis care for years to come and should be a top priority for nephrologists and legislators.

Limitations

The primary purpose of the data in the investigated database is to determine hospital reimbursement under the German DRG system. Consequently, our study is a secondary data analysis using information that was not originally gathered for scientific research. Because the data reflect individual in-hospital stays rather than continuous patient histories, longitudinal trajectories cannot be reconstructed. This approach contrasts other important PD catheter implantation studies applying longitudinal designs.[42,43] However, our method ensures complete coverage and provides reliable real-world data. Our data provides a comprehensive overview of PD catheter implantation numbers and trends across the nation. This comprehensive approach is essential for understanding the current state of PD utilization in Germany and identifying areas for improvement.

Given the retrospective nature of the analysis, bias due to underreporting or overreporting, especially in ICD-coded diagnoses, cannot be ruled out. Nevertheless, claims data on kidney diseases have been proven to have high validity.[44]

Conclusion

Despite all efforts to promote PD in Germany, no relevant changes in utilization were realized during the study period, underscoring the need for rigorous assessment of existing programs – namely by their effect on PD catheter implantation rates.

Abbreviations

ADPKD	Autosomal dominant polycystic kidney disease
AIC	Akaike information criterion

ANOVA	Analysis of variance
BIC	Bayesian information criterion
CHF	Congestive heart failure
CKD	Chronic kidney disease
DRG	Diagnosis related group
GFSO	German Federal Statistical Office
GLMM	Generalized linear mixed model
GN	Glomerulonephritis
HD	Hemodialysis
ICC	Intraclass correlation coefficient
ICD	International Classification of Diseases
ICU	Intensive care unit
IQR	Inter quartile range
KF	Kidney failure
LMM	Linear mixed model
LOS	Length of stay
OPS	German and procedure classification (Operationen- und Prozedurenschlüssel)
PD	Peritoneal dialysis
REML	Restricted maximum likelihood
SD	Standard deviation
SE	Standard error

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Conceptualization: HSW, JCV, NK, FAvSH, BK, KS
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Formal Analysis: HSW, JCV
Investigation: HSW, JCV, NK, FAvSH, BK, KS
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Project administration: KS
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Software: JCV
Supervision: DF, RS, KS
Validation: HSW, JCV, NK, FAvSH, BK, KS,
Visualization: HSW, JCV
Writing – original draft: HSW, JCV
Writing – review & editing: All authors

Declaration of conflicting interests

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Ethical consideration

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Supplemental material

Supplemental material for this article is available online.

Trial registration

Not applicable, as this was a secondary data analysis of pre-existing administrative/statistical data and did not involve a clinical trial or interventional study.

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